water

MDPI

Review

Development-Ecological Protection Conflicts and Coordination at West Taijinel Salt Lake

Xizhuoma Zha [1] and Shaofeng Jia [2,*]

[1] College of Geographic Sciences, Qinghai Normal University, Xining 810000, China; 202147341024@stu.qhnu.edu.cn
[2] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100000, China
* Correspondence: jiasf@igsnrr.ac.cn; Tel.: +86-18-518-075-521

Abstract: The Qaidam Basin in China, recognized for its copious salt lake mineral resources, holds immense significance for the nation's sustenance and industrial progression. However, the escalating exploitation of these resources has led to substantial conflicts between economic pursuits and ecological conservation. Ongoing activities like water diversion for flood control and brine extraction are hindering the preservation of the lake's natural ecosystem. This study examines the challenges of salt lake exploitation and ecological conservation, proposing measures for environmental stewardship. These include delineating the responsibilities of production zones designated for salt lake development; advocating the comprehensive harnessing of flood resources; and establishing a collaborative platform for integrating ecological data among government entities, regulatory bodies, and private enterprises. This research aims to lay the groundwork for ecological management policies for salt lakes in the Qaidam region to balance the development of a top-tier salt lake production base with environmental preservation.

Keywords: Qaidam salt lake; salt lake industrial and mining development zone; natural lake system; salt lake management; salt lake development

Citation: Zha, X.; Jia, S. Development-Ecological Protection Conflicts and Coordination at West Taijinel Salt Lake. *Water* **2024**, *16*, 2139. https://doi.org/10.3390/w16152139

Academic Editor: Bommanna Krishnappan

Received: 17 June 2024
Revised: 19 July 2024
Accepted: 25 July 2024
Published: 28 July 2024

1. Introduction

Salt marshes are particular terrestrial ecosystems that are frequently subject to water inundation, whether it be wet or seasonal. They can be found in coastal areas, estuaries, arid grasslands, salt lakes, and desert zones. These ecosystems have gained worldwide recognition for their significant ecological roles, including water filtration and carbon storage, and are vital for the preservation of environmental well-being [1,2]. Salt marshes are common worldwide [3–5]. In China, they are mainly found in the Inner Mongolia Plateau, Xinjiang Uygur Autonomous Region, and high-altitude areas of the Qinghai–Tibet Plateau [6,7]. The Qaidam Basin in Qinghai is known for its vast salt marshes [8].

The salt marshes in the Qaidam Basin, located in Qinghai Province, cover 3180 square kilometers, about 20% of the basin's total area. Unlike tidal marshes, the Qaidam salt marshes have high salinity levels and abundant mineral resources [9]. The basin holds high-quality mineral deposits with significant reserves. By 2017, it had substantial reserves of potash, lithium chloride, and boron, making up 85%, 80%, and 20% of the national total, respectively. Additionally, the region contributes 88% of the country's potash fertilizer production, with significant mineral resource reserves [10].

Salt lakes in the Qaidam Basin are crucial for the economic development of Qinghai Province and national food and energy security, serving as strategic assets in building an ecological civilization. During his 2016 visit to Qinghai, General Secretary Xi Jinping promoted sustainable development, safeguarding the salt lake, promoting a circular economy, pursuing green development, and ensuring environmentally friendly utilization of salt resources [11]. In 2017, the National Development and Reform Commission released the "13th Five-Year Plan for Western Development", endorsed by the State Council [12]. This plan highlights the comprehensive exploitation of resources in the Qaidam Basin; the promotion of new material industries such as aluminum, magnesium, and lithium in Qinghai Province; and the proactive management of the ecological environment in the Qaidam salt lake area, providing a clear roadmap for the development and safeguarding of Qaidam salt lakes in the upcoming phase.

With the establishment of top-tier salt lake industries, the scale of salt lake operations is growing, leading to a heightened conflict between ecological preservation of lake salt marshes and economic progress. Salt marshes act as important ecological transition zones for aquatic plants and animals, as well as natural flood barriers [9]. The extensive exploitation of resources in recent years has led to declining groundwater levels, reduced salt lake areas, and increased desertification in Qaidam Basin. However, the ecological management of the salt lake in Qinghai Province adheres to the protection laws enacted twenty years ago. As a result, the development zone of the salt lake remains in its initial stages of determining what kind of standard protection is appropriate. The situation exacerbates the conflict between ecological preservation and salt lake development.

Previous generations have attempted to reconcile the conflict between ecological preservation and economic growth by optimizing products and improving resource utilization [13–17]. Few individuals have examined the specific discrepancies between ecological protection requirements and actual development. In this study, we examine the conflict between ecological protection and salt lake development using West Taijinel Salt Lake as a case study. West Taijinel Salt Lake is situated in the central part of Qaidam and is endowed with considerable mineral resources and extensive reserves. Due to the limited specific protection regulations for saline–alkali ecosystems [18]. Current mining activities in the salt lake development zone, such as flood control and brine replenishment, are in conflict with ecological protection requirements. West Taijinel Salt Lake is designated as a development zone, but its flood control and resource management still follow natural lake protocols. Strict adherence to ecological protection standards would impede development, while prioritizing economic growth in this fragile area could result in costly restoration and irreversible ecological harm. This study analyzes conflicts between ecological protection and development in the West Taijinel region, offering management recommendations to address these conflicts and providing a theoretical foundation for formulating ecological management regulations for salt lakes in the Qaidam region.

2. Overview of the West Taijinel Area

2.1. Geographical and Climatic Characteristics

West Taijinel Lake, located at an elevation of around 2680 m in the central region of the Qaidam Basin (37°33′–37°53′ N, 93°13′–93°34′ E), receives an average annual precipitation of about 128.9 mm. The arid conditions lead to an average annual evaporation rate of 1200 to 3500 mm, exceeding precipitation by 9–28 times [19]. The region, a semi-enclosed depression surrounded by higher terrain, has soils primarily made up of silt, fine sand, sandy clay, and glauconite from lacustrine deposits [20]. The arid climate and saline parent material result in desert saline–alkali soils with high salinity and surface salt crust [21,22]. The unique dry climate and underlying surface conditions emphasize the significance of the hydrological systems surrounding West Taijinel Lake for the replenishment and development of saline mineral resources.

2.2. The Hydrological Systems around West Taijinel Lake

The area around West Taijinel Lake is abundant in salt lakes. Yiliping Salt Lake is to the northwest, and to the east are Duck Lake, East Taijinel Lake, West Dabuxun Lake, and East Dabuxun Lake (Chaka Salt Lake). East and West Taijinel Lakes are the terminal lakes of the Nalenggele River, while Dabuxun Lake is the terminal lake of the Golmud River. Figure 1 shows the location of West Taijinel Lake in the Qaidam Basin and its hydrological network. The Nalenggele River naturally divides into multiple tributaries after exiting the mountain pass, with most of its water seeping into groundwater. This groundwater later reunited at the forefront of the alluvial fan, giving rise to the Taijinel River [23]. The Taijinel River splits into the East and West Taijinel Rivers, which flow into the East and West Taijinel Lakes, respectively [24]. The West Taijinel River is the primary water source for West Taijinel Salt Lake. River discharge is mainly in summer and varies annually due to climatic conditions [25]. Between April and September, the flow from the Nalenggele and Taijinel Rivers increases periodically [26]. Due to global warming, the melting of ice and snow in March has caused a rise in natural runoff [27–29]. Annual precipitation has been on the rise since 2013 and 2014 dry spells, reaching 48.68 billion m^3 in 2018.

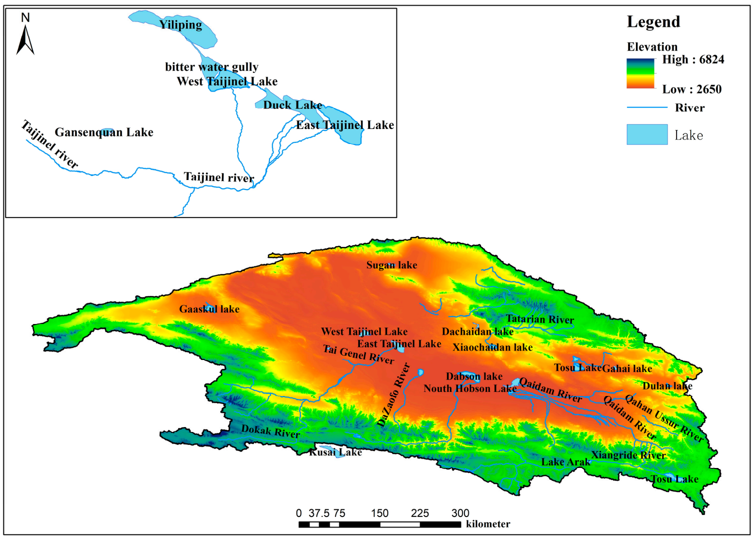

Figure 1. Hydrological map of the salt lakes within the Qaidam Basin and the adjacent water systems of the West Taijinel Salt Lake.

2.3. Ecosystems before and after Development

Before development, East and West Taijinel Lakes played vital ecological roles, such as climate regulation, flood prevention, and dust reduction. They also supported aquatic plants and animals, helping to preserve local biodiversity. However, since 2003, when CITIC Guoan Group acquired mining rights for the West Taijinel Salt Lake and Qinghai Lithium Co. developed the East Taijinel Lake, the natural ecosystem has been greatly altered.

During the flood season, the Taijinel River experiences a significant increase in water flow, leading to the dissolution of mining resources, quality deterioration, and ground subsidence. To guarantee the safety of the resources was authorized by the government in 2008, Qinghai Lithium Co., Ltd., constructed a flood control dam on the southwest side of East Taijinel Lake. Additionally, the CITIC Guoan Group built a flood control dam that spans approximately 45 km on the southern side of West Taijinel Lake. The temporary flood control measure blocked the direct flow between the East and West Taijinel Rivers and Lakes, creating a large artificial lake spanning over 200 km^2, named Duck Lake. Since 1990, West Taijinel Lake has been shrinking at a rate of 3.50 km^2/year [30], and it has completely dried up since 2013. Yiliping Salt Lake was dry before development. However, it maintained some water level post-development by receiving water from the Bitter Water Ditch connected to West Taijinel Lake. Unfortunately, Yiliping Salt Lake dried up after 2014, following West Taijinel Lake. East Taijinel Lake expanded at a rate of 2.19 km^2/year from 1990 to 2002. Due to human interference blocking the hydraulic connection with the Taijinel River from 2011 to 2017, East Taijinel Lake almost dried up. Currently, East Taijinel Lake has been restored to its original surface area [31]. After analyzing the East and West Taijinel lakes' satellite images, we found that the southwest side of the East Taijinel Lake is flat, with noticeable changes, while the east side consists of vast sandy dry salt flats covering about 50 square kilometers and reaching a thickness of 15–20 m. The northwest side of the West Taijinel Lake is elevated, with the southeast side being lower. Shoreline changes mainly occur on the northwest side, and the lake is recharged from the south, reducing shoreline changes. Images of the lakes around West Taijinel Lake and the changes in the area over the years are depicted in Figure 2.

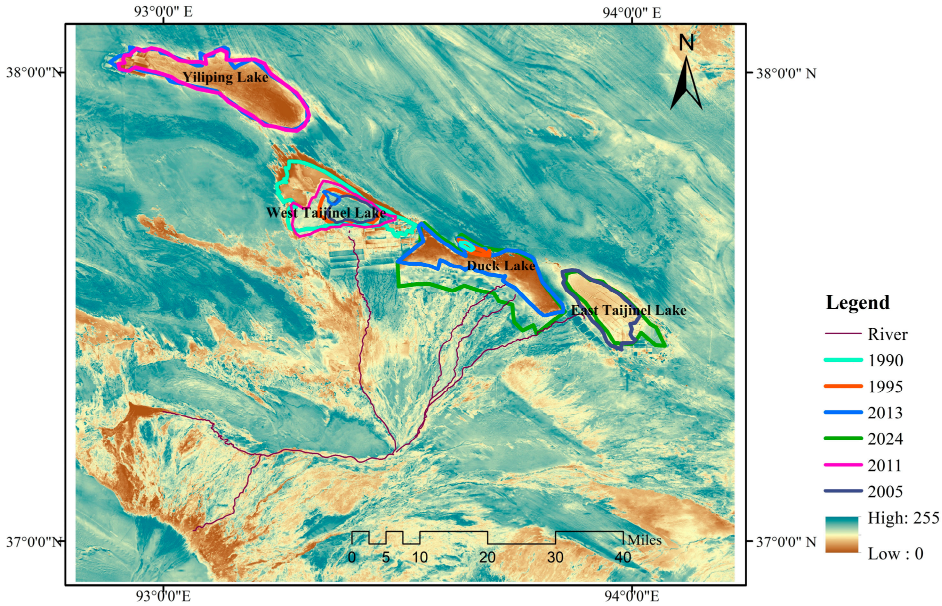

Figure 2. Images of lakes near West Taijinel and the change in lake area over time.

The Duck Lake area expanded from 6.00 km^2 in 2003 to 390 km^2 in 2021. Currently, Duck Lake replaced the dried-up West Taijinel Lake, providing ecological benefits and flood control functions. It facilitates mining activities, stores floodwater, reduces flood flow, and ensures the safety of the salt lake. The saved stormwater runoff aids in salt lake development and can be used for recharge water. The new water surface supports wetland biodiversity and enhances the landscape with unique features, like Yardang landforms. Ecological functions have remained stable. Recently, the area has opened to tourism, attracting visitors due to its scenic beauty and scientific value [32]. Figure 3 shows water circulation and the Nalenggele River of Duck Lake during the 2020 rainy season.

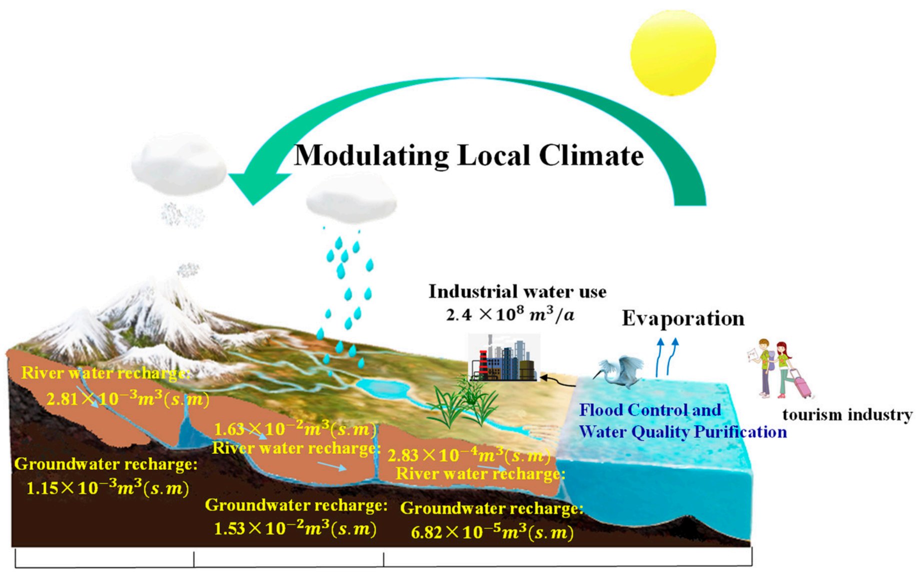

Figure 3. Schematic representation of the hydrological cycle at Duck Lake, encompassing the surface water infiltration rates and groundwater recharge rates across the upper, middle, and lower reaches of the Nalenggele River during the 2020 rainy season [33].

2.4. Brine Replenishment Processes

Salt lake extraction involves collecting brine through channel excavation or well drilling, followed by evaporation in salt pans under arid climatic conditions [34]. With the continuous extraction of shallow, high-grade brine, the inter-crystal brine level decreases. Due to low permeability of salt rock layers, high brine viscosity, and minimal hydraulic gradient, the brine level may not return to pre-extraction levels without a new source, creating an underground brine funnel and risking depletion. Ensuring adequate replenishment to maintain water balance in salt lakes is vital for ecological protection and sustainable resource development [35–38]. The water supply of West Taijinel Lake mainly comes from glacial meltwater from the Nalenggele River (known as Taijinel River downstream) from April to June and from storm floods in July and August. Groundwater recharge mostly comes from water infiltrating the river's mountain outlet into the salt lake region. Floodwaters dissolve salts on the surface of dry salt lakes, which then evaporate and become more concentrated due to the arid climate. These waters either naturally infiltrate the subsurface or are strategically channeled through wells and conduits upon reaching a critical concentration, thereby replenishing underground brine, dissolving valuable elements from mineral deposits, and enhancing the quality of liquid mineral resources [39]. The interactions and transformations between groundwater, river water, and salt lake brine maintain the hydro-saline balance in the salt lake region, crucial for sustainable resource extraction in salt lake areas [40].

3. Conflict between Development and Ecological Protection of West Taijinel Lake

3.1. The Significance of Developing Salt Lake Resources

The use of salt lake resources in the Qaidam Basin has a rich historical background. Since ancient times, residents of the region have engaged in small-scale extraction of sodium salt from areas such as Qinghai Lake, with a focal point on Chaka Salt Lake during the Eastern Han Dynasty. Over time, extraction activities diversified to include boron minerals, gypsum, and natural soda during the late Qing Dynasty. In 1949, significant progress in large-scale production transformed salt lake resources in the Qaidam Basin into five key industrial clusters: potash, sodium salt, magnesium salt, lithium salt, and chlor-alkali [41]. Particularly noteworthy advancements have been made in Qarhan Salt Lake, East Taijinel Salt Lake, West Taijinel Salt Lake, and Yiliping Salt Lake [23]. The East and West Taijinel Lakes and adjacent Yiliping Lake deposits contain lithium, boron, and potash reserves of various sizes, indicating substantial mineral resources. The brine resource reserves are estimated at 1.6323, 0.9258, and 13.6959 million tons, underscoring the significant potential of these mineral resources. Considering geological exploration reserves and current market prices, the projected values of lithium carbonate, potassium carbonate, and boric acid in West Taijinel Lake, East Taijinel Lake, and Yiliping Salt Lake were estimated to be 0.28 trillion yuan (approximately USD 38.5 billion) [42]. Details of the production capacity and reserve requirements of lithium carbonate, potassium sulfate, and boric acid in these three salt lakes are depicted in Figure 4.

The West Taijinel Salt Lake deposit spans an area of 570 km^2 and is a significant brine lithium deposit with lithium metal reserves totaling 505,000 tons [43]. Its annual production comprises 400,000 tons of potassium sulfate, 10,000 tons of battery-grade lithium carbonate, 10,000 tons of refined boric acid, and 50,000 tons of magnesium oxide [44,45]. In June 2021, General Secretary Xi Jinping visited the salt lake in Qaidam and stressed the importance of accelerating the construction of a world-class salt lake production base, which is strategically and economically significant [46].

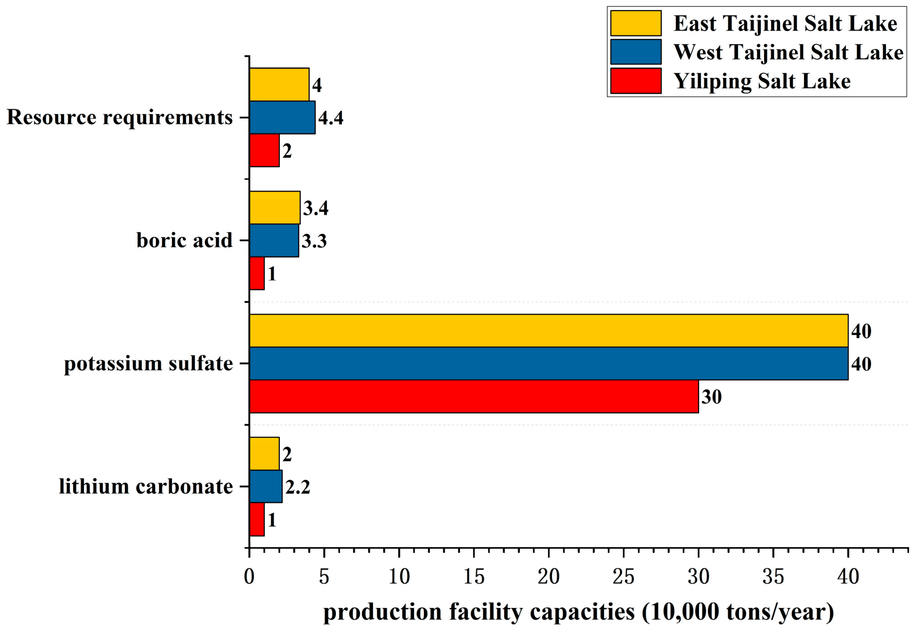

Figure 4. Production unit sizes and resource requirements for lithium carbonate, potassium sulfate, and boric acid across three salt lakes.

3.2. The Importance of Ecological Conservation

The Qaidam Basin is an isolated ecosystem, classified as one of China's 19 key ecologically fragile regions and one of the country's eight major deserts. It has the highest elevation and the largest desertification area among these deserts. Its simple ecosystem structure, low productivity, poor stability, and weak self-recovery capacity make it highly vulnerable to external disturbances. Restoring this area is extremely challenging due to its slow recovery process and high restoration costs [47]. In recent decades, the Qaidam Basin has suffered substantial ecological damage from climate change and human activities. This has led to severe desertification, covering 10.964 million hm^2 by 2020; extensive grassland degradation of 561,000 hm^2; habitat loss for various species, deteriorating living conditions; and shrinking lakes [48]. In 2016, General Secretary Xi Jinping emphasized that "Qinghai's greatest value, responsibility, and potential lie in its ecology". Ref. [11] highlighted the crucial importance of ecosystems for the ecological security of both Qinghai Province and the nation as a whole [49].

The Qaidam salt lakes are important industrial sites in China but are also delicate ecosystems. The tension between ecological preservation and extensive resource extraction from salt lakes is increasing [50]. To ensure the sustainable development of salt lake resources and ecological protection, the government has implemented policies and regulations. The "Qinghai Province Salt Lake Resources Development and Protection Regulations", effective from 1 August 2001, require adherence to environmental protection laws. These laws include the River and Lake Chief System, Water Resources Management Regulations, Water Withdrawal and Utilization Management Measures, and Ecological Management Regulations. For West Taijinaier Lake, the key points of these regulations are as follows:

- Manage lake shorelines to preserve their natural shape;
- Permit and supervise water extraction for projects;
- Remove flood control dikes to restore ecological water flow and the water surface of West Taijinaier Lake;
- Ensure and require the correction of illegal encroachments on river and lake shorelines.

While most protective regulations apply to managing salt lake ecosystems, some aspects of ecological protection do not align with the requirements of development zones. Current regulations for managing salt lake development zones are based on regulations for natural lakes, leading to conflicts between development activities like brine extraction, transportation, flood control, and ecological protection needs.

3.3. Conflict of Position between the Salt Lake as a Mineral and Mineral Development Area and the Protection of the Natural Lake State

Terminal lakes play a vital role in watershed ecosystems. In the West Taijinel region, downstream river ecosystems sustain algae and black-necked cranes during the summer. Consequently, apart from their contributions to climate regulation, flood control, and dust mitigation, terminal lakes provide habitats for aquatic flora and fauna, preserving biodiversity. West Taijinel Lake, however, deviates from traditional terminal lakes, as it falls within a salt lake development zone where mining activities have been permitted. These activities, aimed at brine extraction, have disrupted the natural landscape of the lake, altering its water depth based on extraction needs and hindering the maintenance of a consistent surface area. The enterprises' actions have caused changes and the potential disappearance of the lake surface. While ecological guidelines stress the importance of preserving natural lake shorelines, enterprises face a dilemma, as they are required to restore the lake surface while also utilizing it for resource extraction purposes.

3.3.1. Flood Control Measures May Conflict with Ecological Protection Efforts

During the flood season, the Taijinel River's inflow into West Taijinel Salt Lake can reach 20–30 m^3/s. High-water years occur every 3–5 years, with extreme floods about every decade. The flat terrain can cause the lake and river to merge, expanding the lake's surface area significantly, which can harm salt lake resources. Constructing flood control facilities and storage is essential for effective salt lake exploitation.

The initial temporary flood protection dikes evolved into permanent flood control structures. The two enterprises within West Taijinel Salt Lake are classified as large-scale, necessitating Level II flood control capacity for the dam. Dams are currently undergoing expansion and reinforcement to optimize flood protection. Section 2.3 discusses that the East and West Taijinel River are the primary source of recharge for the West Taijinel Lake before development. However, a levee was built, disrupting the connection between the rivers and the lake, leading to the gradual drying up of the lake due to mineral mining. Restoring the natural ecology requires dismantling the levee and draining ecological water to preserve the lake's original appearance. However, this action may result in flooding downstream, impact mineral quality, and cause economic losses, highlighting the conflict between protecting the lake's ecology and its development.

3.3.2. An Abstraction License Be Sought for Flood Resources?

Water resources are crucial for salt lake development. The extraction and transportation of brine both require substantial amounts of water. For the relatively remote West Taijinel Salt Lake, floodwaters are a critical resource for development. Duck Lake's flood management demands compliance with flood control-scheduling directives. Following each flood event during the flood season, water must be discharged to reduce the storage level below the flood limit level, as mandated. Saline lake enterprises funnel the regulated, evaporatively concentrated brine into salt lake mining regions for ore dissolution, deeming this practice beneficial for comprehensive flood resource utilization. However, according to water resource management regulations, this constitutes unauthorized water use and necessitates a water withdrawal permit. Evidently, there are conflicting viewpoints among departments regarding the utilization of Duck Lake's flood resources.

Furthermore, the unaltered natural intermittent river channel, known as Kushuigou, connects Duck Lake, West Taijnel Lake, and Yiliping Salt Lake. However, companies have modified this channel to transport brine to dissolve ore. In accordance with the regulations governing river chief systems, these actions constitute the unauthorized occupation of a natural river channel by enterprises. Although management regulations in the salt lake region are still being formulated, discussions regarding the appropriate management and treatment of this issue are ongoing. The specific conflicts between ecological management and salt lake development are presented in Table 1.

Table 1. The ecological protection and conflicts present in the West Taijinel Lake.

Ecological Protection Content	Reference to Regulations	Current Status of Management	Major Conflicts
Lake shoreline management	"Guidelines for the Implementation of the River and Lake Length System", "Regulations on Water Resources Management in Haixi Mongol and Tibetan Autonomous Prefecture"	Strengthening shoreline management and preserving natural lake shorelines	The natural landscape has been permanently changed due to development and cannot be fully restored to its original state while meeting ecological preservation standards.
Floodwall management	"Guidelines for the Implementation of the River and Lake Length System"	Removing floodwalls and restoring natural lake waters	After removing the flood wall, the flood season may impact the quality of resources in the mining area, affecting enterprise development.
Natural watercourses management	"Guidelines for the Implementation of the River and Lake Length System"	Illegal occupation of natural watercourses	The Bitterroot has been managed as an internal production area and cannot be returned to its natural state.
Flood resource management	"Regulations on Water Resources Management in Haixi Mongol and Tibetan Autonomous Prefecture"	Application for water-abstraction permit	After evaporation, floodwater resources used by enterprises become brackish water with a high salt concentration, which falls outside the realm of water resource management.

4. Mitigation Options

4.1. Defining the Functional Position of the Salt Lake Resource Development Zone

In 2021, Lu Zhao et al. conducted a study on the ecological water resources in West Taijinel Salt Lake. They observed that the average annual footprint from 2010 to 2018 was 1.1206 × 106 ghm^2. The ecological carrying capacity of the region has been increasing annually, with an 82.3% rise by 2018, primarily influenced by the precipitation control [51]. At present, the Western Taijinel region has enjoyed ecological security and sustainable water resource management, and Duck Lake can fully support the local ecosystem [52,53]. Generally, the development of salt lakes should prioritize the preservation of the functionality of salt lake wetlands.The maintenance of salt lake wetland functions should be flexible, provided that the overall wetland functions of the area are preserved.Modifications to lake depth or lake surfaces should be allowed as long as the overall ecological function is maintained. It is crucial for government-planned salt lake development zones to establish clear development goals to maximize economic benefits, preserve ecological functions, and promote sustainable development. The Mineral Resources Law grants mining license holders broad rights to manage mineral resources. Common development activities like water diversion, storage, and provision for brine concentration are standard practices for salt lake enterprises.

4.2. The Principles and Flexibility of Wetland Conservation

Salt lake wetlands are vital ecosystems in arid regions, necessitating a balanced approach that emphasizes both protection and sustainable development over absolute preservation. China's Wetland Protection Law aligns with "Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat", emphasizing the rational conservation and utilization of wetlands with specific ecological functions [54]. Many salt lakes worldwide are protected under the "Ramsar Convention", with over 200 countries participating to safeguard 3870 wetlands, including 202 permanent inland salt lakes and 405 coastal saline lakes [55]. The ecological protection of salt lakes refers to relevant regulations.

4.2.1. Flood Barrier Management

In West Taijinel, enterprises have constructed water-diversion and -storage facilities to manage flood events, ensure mining safety, and create new water surfaces. These artificial water bodies replace natural salt lake water, preserving wetland functions and supporting salt lake mining. Consequently, flood control in salt lakes can be integrated with salt lake production and the maintenance of wetland functions. Additionally, enterprises holding mining rights can extract, transport, and replenish brine while meeting ecological protection standards. This approach balances the ecological protection requirements of the development zone with the production needs of enterprises. While the document should clarify flood control standards for Duck Lake and the multifunctional use of Bitter Water Ditch for flood discharge and brine transmission, it should also rigorously design the flood-limit water level and ecological water level for the West Taijinel area.

4.2.2. Flood Resources and Management

In the arid Qaidam Basin, where water resources are scarce, strict water-extraction management procedures have been implemented by the central government to ensure ecological water needs. These procedures include comprehensive planning of basin water resources, medium-to-long-term water resource scheduling, environmental impact assessments for projects, water resource impact assessments for construction projects, and the application and supervision of water extraction permits. Recent government policies have introduced the "Three Red Lines": a red line for water extraction, water use efficiency, and wastewater discharge. These policies require each province and county to set upper limits for water extraction. As a result, water use efficiency in the West Taijinel region has significantly improved, ensuring sustainable water resource development and ecological security.

The floodwater released from Duck Lake for mining activities serves as a secondary use after meeting ecological water functions. This water, sourced from riverine ecological base flows and floods, fulfills the ecological water needs of the terminal lakes. Therefore, the water used for mining from Duck Lake does not increase the total water use in the basin but rather represents a reuse of ecological water from terminal lakes. To address water scarcity in the West Taijinel region, promoting the integrated use of floodwater resources is recommended. Meanwhile, maintaining a certain water surface area in the lake is essential to preserve the wetland's ecological functions, and water extraction for mining should not go below the ecological water level limit.

5. Conclusions and Future Perspective

In the fall of 2023, the Central Fifth Ecological and Environmental Protection Inspection Team expressed concerns about the unorthodox expansion, unauthorized water extraction, and encroachment on grasslands by certain enterprises in the Qaidam Salt Lake area of Qinghai. The aforementioned issues have had adverse effects on local ecosystems. Ensuring the green and sustainable development of salt lake resources in the Qaidam Basin remains a significant challenge [56,57]. To promote balanced growth between ecological construction and the economy, tailored management recommendations considering the unique development characteristics of salt lakes are essential.

5.1. Clarify the Positioning of Production Areas in Planned and Authorized Salt Lakes to Avoid Unreasonable Requirements for Maintaining the Lake Surface

Managers must carefully consider the diverse ecosystems within the salt lake development area, encompassing salt extraction, avian habitats, and recreational activities, to formulate comprehensive plans. It is crucial to delineate the boundaries of the salt lake mineral development zone to meet the strategic objectives of creating a world-class salt lake development area. These designated zones should be classified as production areas, with specific regulations for production and ecological environment protection management.

Given the creation of Duck Lake, restoring East and West Taijinel Lakes to their original states is not feasible. To ensure Duck Lake's ecological functionality, it is essential to facilitate water surface movement while maintaining a specific lake area. The goal is to preserve the original water surface of Taijinel Lake without necessitating complete restoration. Furthermore, the water diversion channels, brine extraction channels, and brine transportation channels (including bittern ditches) within the salt lake production area should be treated as internal production channels of enterprises, provided they meet flood control standards.

Regulating the brine level dynamics in the salt lake production area is crucial to prevent adverse environmental impacts and maintain normal production activities. The flood control levee at Duck Lake serves as vital infrastructure for ensuring enterprise safety during the flood season; however, levee management must comply with coordination requirements set forth by flood control authorities. Post-development, enterprises must ensure the non-hazardous treatment of developed areas, adhering to ecological safety standards.

5.2. Revision of the Regulations on the Development and Protection of Salt Lake in Qinghai Province

Saline–alkaline environments are often undervalued, leading to a lack of strict laws and policies to prevent their degradation. Human activities can harm these environments, but this can be reduced by altering management policies and implementing safety regulations for relevant industries, thereby achieving a balance between economic development and ecological preservation [58]. For instance, after a 67% decrease in water volume at Great Salt Lake, USA, salinity significantly increased. The Clean Air Act of 1963 contributed to the lake's recovery, with a 25-fold decrease in metal concentrations in surface sediments [59]. Reduced mining and enhanced pollution control measures since the 1980s were key factors in this improvement.

The Regulations on the Development and Protection of Salt Lakes in Qinghai Province, implemented in August 2001, have shaped the use of salt lake resources for twenty years. However, these regulations are no longer aligned with the current state of salt lake resource development. Article 6 of the regulations emphasizes that the development of salt lake resources must comply with the environmental protection laws. It highlights the principle of "who develops, who protects, who destroys, who compensates, who pollutes, who manages, and strive to protect the ecological environment of salt lake resources and mining areas". This principle is sound, but further clarification is necessary to define what constitutes the destruction and pollution of the salt lake. In the development zone, it is not possible to completely prevent destruction, but it is necessary to maintain the ecological function of the area without causing significant harm. This includes allowing for appropriate movement of the water surface location, as long as it is performed in a way that maintains a certain water surface level. It is not mandatory for enterprises to restore the salt lake to its original state during development, but they may be obligated to restore the ecology post-development. This restoration process should encompass not only returning the area to its former state but also taking into account environmental safety, landscape compatibility, habitat diversity, and ecological equilibrium. These principles should guide the restoration process to ensure successful and sustainable outcomes.

Improving the definition of mining depth for deep and open-pit mining in the Regulations on the Exploitation and Protection of Salt Lakes in Qinghai Province is necessary to provide clarity. Currently, the well mining of West Taijinel Salt Lake reaches a depth of 100 m, and the decision to use open-pit mining is left to the enterprise and management unit. However, the regulations do not clearly define the scope of deep mining and open-pit mining, highlighting the need for specific guidelines on monitoring mining depth by the Bureau of Land and Resources.

To address ecological disturbances from illegal construction and grassland encroachment in the Qaidam Basin, stricter legislation is needed. Remote sensing and Geographic Information Systems (GIS) can aid in monitoring water resources in these areas [60]. Jain et al. (2005) suggest dividing the development area into three priority zones for conservation planning: urgent attention areas, moderately sensitive areas, and land use/land cover classifications. Prioritizing these zones can enhance conservation efforts [61].

5.3. Implement a Three-Tier Integrated Approach to Develop a Comprehensive Ecological Data Platform

Collaboration among government, enterprises, and public is crucial to protect the ecological development of salt lake regions. Successful global precedents such as conservation efforts for Mono Lake have demonstrated the effectiveness of this approach. After extensive protests and scrutiny, collaborative efforts among governments, private organizations, and the public were initiated to restore lake water levels [62]. To develop salt lakes in the Qaidam Basin, enterprises should prioritize ecological enhancement, improve mineral resource utilization, accelerate high-end product research, and establish a green economic model. Furthermore, they need to improve their management systems and systematically monitor the surrounding ecological environment, including lake depth, evaporation rates, biodiversity, groundwater quality, soil composition, and extraction depths. To achieve these goals, a three-tier collaboration between government and law enforcement agencies should be implemented to develop a comprehensive ecological data platform. This platform will allow for quantifying ecological changes, sharing ecological data, analyzing the threshold values of ecological impact factors, and establishing ecological management standards based on these thresholds. This approach will be highly effective by refining the ecological management mechanism, enhancing the overall management level and efficiency, and providing real-time management support for the synergistic economic and ecological development of the development zone.

5.4. Coordinated Management

In May 1999, the Qinghai Provincial Land and Resources Department's Salt Lake Administration and the Golmud Qarhan Salt Lake Administration were established. According to the 2016 Salt Lake Administration Work Report, the primary focus of the administration was on the supervision and management of salt lake mineral resources and the collection of mineral resource compensation fees, with a relatively low administrative level [63]. It is essential to dismantle the barriers of individual salt lake management units and enhance inter-governmental coordination. Differentiated resource and environmental management should be implemented based on the characteristics of each salt lake development zone, exploring the establishment of an ecological capital asset liability statement and establishing resource utilization, environmental performance inventory management, and exit and compensation mechanisms. Additionally, a comprehensive plan for the coordinated development of ecology and salt lakes should be devised, addressing issues such as the protection of strategic alkali resources and the reserve of alkali products.

The development of the salt lake industry in Qaidam is crucial for the economic growth of Qinghai Province and China. To meet President Xi's goal of establishing a top-tier salt lake production base and align with the objectives of the "14th Five-Year Plan" and the "One Belt, One Road" strategy, it is essential to comprehensively consider economic construction and ecological protection in the development zone. Strengthening relevant laws and regulations, clarifying the authority and responsibilities of administrative units, enhancing regulations and documents, defining management rights and responsibilities, rationalizing the development and management of salt lakes, and addressing conflicts between enterprises and management requirements are the key steps to achieving a balance between building a world-class salt lake production hub and preserving the environment. This will lead to the high-quality development of the salt lake area.

Author Contributions: The conceptualization of this work was the responsibility of S.J. The manuscript underwent review and editing by X.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This study was financially supported by the Major Research Project of Qinghai Province Program (No. 2019-SF-A4).

Data Availability Statement: No novel data were generated or assessed in this research endeavor. Data dissemination is not pertinent to the present manuscript.

Acknowledgments: We extend our gratitude and thanks to the anonymous reviewers for their insightful and constructive feedback, which greatly enhanced the manuscript. We are also indebted to the members of the Journal Editor Board for their invaluable assistance and patience throughout the review process.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. MacDonald, G.K.; Noel, P.E.; Chmura, P.G.L. The legacy of agricultural reclamation on channel and pool networks of bay of fundy Salt Marshes. *Estuaries Coasts* **2010**, *33*, 151–160. [CrossRef]
2. Barbier, E.B.; Hacker, S.D.; Kennedy, C.; Koch, E.W.; Stier, A.C.; Silliman, B.R. The value of estuarine and coastal ecosystem services. *Ecol. Monogr.* **2011**, *81*, 169–193. [CrossRef]
3. Negrin, V.L.; Pratolongo, P.D.; Villalobos, A.E.D.; Botté, S.E.; Marcovecchio, J.E. Biomass, decomposition and nutrient cycling in a SW Atlantic Sarcocornia perennis marsh. *J. Sea Res.* **2015**, *97*, 50–55. [CrossRef]
4. Desroches, M.B.; Lavoie, M.; Lavoie, C. Establishing the value of a salt marsh as a potential benchmark: Vegetation surveys and paleoecological analyses as assessment tools. *Botany* **2013**, *91*, 774–785. [CrossRef]
5. Williams, R.J.; Allen, C.B.; Kelleway, J. Saltmarsh of the Parramatta River-Sydney Harbour: Determination of cover and species composition including comparison of API and pedestrian survey. *Cunninghamia A J. Plant Ecol. East. Aust.* **2011**, *12*, 29–43.
6. Liu, W.; Gao, R.; Zhang, Q.; Chen, Y.; Xing, X.; Bai, Z.; Jia, L.; Yu, X. Diversity and evaluation of phytoplankton in salt marsh wetland of Ordos Plateau. *J. Arid. Land Resour. Environ.* **2009**, *23*, 143–148.
7. Liu, W.; Liu, A.; Tie, N.; Gao, R.; Zhang, Q. Study on ecological environment characteristics of desert salina wetland in Inner Mongolia. *Guangdong Agric. Sci.* **2013**, *40*, 158–162.
8. Wang, L. Study on Plant Eco-Stoichiometry of Salt Marsh Zone in Salt Lake of Qaidam Basin. Master's Thesis, University of Geosciences, Beijing, China, 2019.
9. Dale, P.; Eslami-Andargoli, L.; Knight, J. The impact of encroachment of mangroves into saltmarshes on saltwater mosquito habitats. *J. Vector Ecol.* **2013**, *38*, 330–338. [CrossRef] [PubMed]
10. Liu, W.; Zhang, Q. Study on the Lowest Ecological Water Level of Inner Mongolia Desert Salt Marsh Wetland. *Guangdong Agric. Sci.* **2013**, *40*, 150–152+166.
11. Cai, G. Haixi Strives to Build a World-Class Salt Lake Industrial Base. Available online: http://www.cdmrb.com.cn/pc/202108/26/c73426.html (accessed on 4 November 2021).
12. Zhang, Q. Xi Jinping Emphasizes the Importance of Respecting, Adapting to, and Protecting Nature, and Advocates for the Robust Establishment of a National Ecological Security Barrier. Available online: http://www.xinhuanet.com/politics/201608/24/c_1119448608.htm?from=groupmessage&isappinstalled=0 (accessed on 13 January 2024).
13. Hu, Y.; Su, H.; Zhu, Z.; Qi, T.; Pang, Q. Environmentally benign techniques of lithium extraction from salt lakes: A review. *Environ. Chem. Lett.* **2024**, *22*, 105–120. [CrossRef]
14. Li, H.; Li, L.; Li, W. The extraction rules investigation of mental(Li, Na, K, Mg, Ca) ion in salt lake brine by TBP-$FeCl_3$ extraction system. *Chem. Phys. Lett.* **2021**, *763*, 138249. [CrossRef]
15. Li, R.; Wang, W.; Wang, Y.; Wei, X.; Cai, Z.; Zhou, Z. Novel ionic liquid as co-extractant for selective extraction of lithium ions from salt lake brines with high Mg/Li ratio. *Sep. Purif. Technol.* **2021**, *277*, 119471. [CrossRef]
16. Li, H.; Li, L.; Li, W. Lithium extraction from salt lake brine with high mass ratio of Mg/Li using TBP-DIBK extraction system. *Separations* **2022**, *10*, 24. [CrossRef]
17. Li, H.; Li, L.; Li, W. Study of lithium extraction mechanism by TBP extraction system. *Chem. Phys. Lett.* **2022**, *791*, 139371. [CrossRef]
18. Williams, W.D. Environmental threats to salt lakes and the likely status of inland saline ecosystems in 2025. *Environ. Conserv.* **2002**, *29*, 154–167. [CrossRef]
19. Ma, S. Study on ecological environment protection in Qinghai Lake region. *J. Poyang Lake* **2010**, *4*, 68–77.
20. Wang, Y.; Chen, T.; Wu, C.; Lai, Z.; Guo, S.; Cong, L. A Chronological Study on the Sedi-mentation of the West Taijinel Lake in the Qaidam Basin. *Rid Land Geogr.* **2019**, *42*, 876–884.
21. Liu, Y.H. *Water Resource Reasonable Exploitation and Environmental Protection in Qaidam-Basin*; Science Press: Beijing, China, 2000.
22. Zhong, Z.B.; Zhou, G.Y.; Yang, L.C.; Liu, H.; Song, W. The biomass allocation patterns of desert shrub vegetation in the Qaidam Basin. *J. Desert Res.* **2014**, *34*, 1042–1048.

23. Yu, J.Q.; Gao, C.L.; Cheng, A.Y.; Liu, Y.; Zhang, L.S.; He, X.H. Geomorphic, hydroclimatic and hydrothermal controls on the formation of lithium brine deposits in the Qaidam Basin, northern Tibetan Plateau, China. *Ore. Geol. Rev.* **2013**, *50*, 171–183. [CrossRef]
24. Sun, Y.; Li, J. Study on the dynamic changes of brine in West Taijina. *Ground Water* **2014**, *5*, 102–103.
25. Zhang, J.; Wang, Y.; Li, C.; Wu, Y. Analysis on development and utilization of water resources in Nalingguole River of Qaidam Basin. *Groundwater* **2014**, *36*, 166–167.
26. Wang, J.; Liu, J.; Pan, M. Flood control contingency scheme for tail area of Nalenggele River. *Yellow River* **2018**, *40*, 53–55.
27. Liu, Y.H.; Li, H.M.; Wen, T.T.; Shen, H.; Han, Z.; Zhu, B. Risk Zoning of Summer Rainstorm Disaster and Its Influence in Qaidam Basin. *Arid. Zone Res.* **2021**, *38*, 757–763.
28. Lu, N. Changes of lake area in Qaidam basin and the influence factors. *J. Arid Land Resour. Environ.* **2014**, *28*, 83–87.
29. Fu, X.C.; Wang, F.; Wang, H.; Duan, S. Analysis of Long-Term Changes Intemperature and Precipitation and Their Relationships with Water Resources in the Qaidam Basin in China. *Resour. Sci.* **2011**, *33*, 408–415.
30. Chen, Y.; Zhuge, Y.; Shi, Y.; Du, Q.; Zhang, X.; Nie, R. Identification of natural eco-hydrological characteristics of lakes in the Qaidam Basin. *Water Resour. Prot.* **2023**, *39*, 225–233.
31. Li, L.; Ni, W.; Li, T.; Zhou, B.; Qu, Y.; Yuan, K. Influences of anthropogenic factors on lakes area in the Golmud Basin, China, from 1980 to 2015. *Environ. Earth Sci.* **2020**, *79*, 20. [CrossRef]
32. Mao, X.; Liu, X.; Dong, Y. Research on the genesis of semi-submerged yardan land form in the duck lake area of qaidam basin. *Geol. Rev.* **2018**, *64*, 1505–1518. (In Chinese)
33. Han, G.; Han, J.B.; Liu, J.B. Variation Characteristics of LiCl Deposit under Condition of Mining in East Taijnar Salt Lake, Qaidam Basin. *Inorg. Chem. Ind.* **2020**, *25*, 17–22, (In Chinese with English Abstract).
34. Chen, Y. Analysis of dynamic changes in the underground brine water level characteristics in the west Taijinel salt lake mining area. *Ground Water* **2018**, *40*, 3.
35. Wang, J.W.; Huang, J.T.; Fang, T.; Song, G.; Sun, F.Q. Relationship of Uunderground Water Level and Climate in Northwest China's Inland Basins under the Global Climate Change: Taking the Golmud River Catchment as an Example. *China Geol.* **2021**, *4*, 402–409.
36. Yin, L.H.; Xu, D.D.; Jia, W.H.; Zhang, X.X.; Zhang, J. Responses of Phreatophyte Transpiration to Falling Water Table in Hyper-Arid and Arid Regions, Northwest China. *China Geol.* **2021**, *4*, 410–420.
37. Zhang, X.; Li, H.; Jiao, J.J.; Luo, X.; Zuo, J.; Lu, M.; Liu, Y.; Liang, W.; Kuang, X. Control factors on nutrient cycling in the lake water and groundwater of the Badain Jaran Desert, China. *J. Hydrol.* **2021**, *598*, 126408. [CrossRef]
38. Xu, W.; Su, X.; Dai, Z.; Yang, F.; Zhu, P.; Huang, Y. Multi-tracer investigation of river and groundwater interactions: A case study in Nalenggele River basin, northwest China. *Hydrogeol. J.* **2017**, *25*, 2015. [CrossRef]
39. Zhang, Y.S.; Zheng, M.P. Metallogenic models of potassium ore deposits in China and demonstration of deep exploration technology. *Earth Sci. Front.* **2021**, *28*, 1–9.
40. Bischoff, J.L.; Israde-Alcántara, I.; Garduño-Monroy, V.H.; Shanks Iii, W.C. The springs of Lake Pátzcuaro: Chemistry, salt-balance, and implications for the water balance of the lake. *Appl. Geochem.* **2004**, *19*, 1827–1835. [CrossRef]
41. Wang, Z.; Shi, Z.; Tong, H.; Ren, X.; Shi, H. Analysis of salt lake resource security capacity in Qinghai qaidam basin and countermeasure research. *China Min. Mag.* **2023**, *32*, 38–42.
42. Tang, F.; Xie, A.; Zan, C. Development status and countermeasure research of brine resources in the east and west Taijinel salt lakes and the yiliping salt lake. *Ind. Miner. Process.* **2020**. [CrossRef]
43. Zhou, H.; Tang, J.; Guo, J.; Dai, Y.; Li, G.; Yan, B. Integrated system of comprehensive utilizing the concentrated brine of Yuncheng salt-lake basing on salt-forming diagram. *Chin. J. Chem. Eng.* **2019**, *27*, 182–190. [CrossRef]
44. Zhang, X.Y.; Ma, H.Z.; Gao, D.L.; Wang, T.; Yang, Z.H.; Zhang, M.G. Dynamic changes of K, Li and B in hydrochemistry in brine of the mining area of taijinair salt lake during the initial period of mining. *J. Lake Sci.* **2007**, *19*, 727–734.
45. Yu, M.X.; Li, L.G.; Chen, Y.J.; Qin, J.Z.; Liu, H. Grade variation in the past mining years and it's forecast in the next 10 years of potassium, boron, lithium and magnesium in west Taijinel salt lake brine. *J. Salt Lake Res.* **2021**, *29*, 98–103.
46. Zheng, M.; Hou, X. Comprehensive utilization and sustainable development strategy of Qinghai salt lake resources. *Sci. Technol. Rev.* **2017**, *35*, 11–13.
47. Ma, Y.; Li, P.; Xiao, L.; Wang, B.; Xu, Y.; Pan, J. Identification of Key Areas for Ecological Restoration and Division of Restoration Zones in Qinghai Province. *J. Soil Water Conserv.* **2024**, *38*, 252–265.
48. Li, S.; Chen, Y. Thoughts on Ecological Construction of Qaidam Basin. *For. Grassl. Policy Res.* **2021**, *1*, 68–72.
49. Wan, W.; Long, D.; Hong, Y.; Ma, Y.; Yuan, Y.; Xiao, P.; Duan, H.; Han, Z.; Gu, X. A lake data set for the Tibetan Plateau from the 1960s, 2005, and 2014. *Sci. Data* **2016**, *3*, 160039. [CrossRef] [PubMed]
50. Li, L.; Ni, W.; Cheng, Y.; Wang, H.; Yuan, K.; Zhou, B. Evaluation of the eco-geo-environment in the Qaidam Basin, China. *Environ. Earth Sci.* **2021**, *80*, 27. [CrossRef]
51. Zhao, L.; Wang, X.; Ma, Y.; Li, S.; Wang, L. Investigation and assessment of ecological water resources in the salt marsh area of a salt lake: A case study of West Taijinar Lake in the Qaidam Basin, China. *PLoS ONE* **2021**, *16*, e0245993. [CrossRef]
52. Darnault, C.J.G. Sustainable development and integrated management of water resources. In *Overexploitation and Contamination of Shared Groundwater Resources*; Springer: Dordrecht, The Netherlands, 2008; pp. 309–324.
53. Jiani, D. Status Quo, Problems and countermeasures of water resources in Qaidam Basin. *Sci. Technol.* **2013**, *17*, 263.

54. Wang, R.; Zhang, M.; Wu, H.; Li, Y. Analysis on wetland definition and classification of the wetland conservation law of the People's Republic of China. *Wetl. Sci.* **2022**, *20*, 404–412.
55. RSIS. Ramsar Sites Information Service. 2020. Available online: https://rsis.ramsar.org/ris-search/?f[0]5wetlandTypes_en_ss:Inland%25%2020wetlands (accessed on 15 September 2020).
56. Ministry of Ecology and Environment: Unregulated expansion of Salt Lake Resource Development in the Qaidam Basin, Qinghai Province, Intensifies the Ecological and Environmental Burden. Available online: https://www.mee.gov.cn/ywgz/zysthjbhdc/dcjl/202312/t20231201_1057812.shtml (accessed on 1 December 2023).
57. Central Ecological and Environmental Protection Inspectorate: Qinghai Salt Lake Group and other Enterprises Have Been Illegally Taking Water for a Long Time. Available online: http://www.jwview.com/jingwei/html/05-09/317323.shtml (accessed on 9 May 2020).
58. Williams, W.D. Lake Corangamite, Australia, a permanent saline lake: Conservation and management issues. *Lakes Reserv. Res. Manag.* **1995**, *1*, 55–64. [CrossRef]
59. Paul, V.G.; Mormile, M.R. A case for the protection of saline and hypersaline environments: A microbiological perspective. *FEMS Microbiol. Ecol.* **2017**, *93*, fix091. [CrossRef] [PubMed]
60. Tourian, M.J.; Elmi, O.; Chen, Q.; Devaraju, B.; Roohi, S.; Sneeuw, N. A spaceborne multisensor approach to monitor the desiccation of Lake Urmia in Iran. *Remote Sens. Environ.* **2015**, *156*, 349–360. [CrossRef]
61. Jain, A.K.; Das, S.K.K.; Goyal, S.A.K. Conservation Planning of Sambhar Lake, Rajasthan Using Satellite Remote Sensing and GIS. M.tech Thesis, Andhra University, Visakhapatnam, India, 2005.
62. Shadkam, S.; Ludwig, F.; van Vliet, M.T.; Pastor, A.; Kabat, P. Preserving the world second largest hypersaline lake under future irrigation and climate change. *Sci. Total Environ.* **2016**, *559*, 317–325. [CrossRef] [PubMed]
63. Yang, R.; Meng, W.; Shu, J.; Li, X.; Sun, M.; Zhang, Y. Ecological Civilization Construction for the Saline Industry in Qaidam Basin. *Strateg. Study CAE* **2017**, *19*, 51–57. [CrossRef]